HETCH HETCHY PROJECT

by

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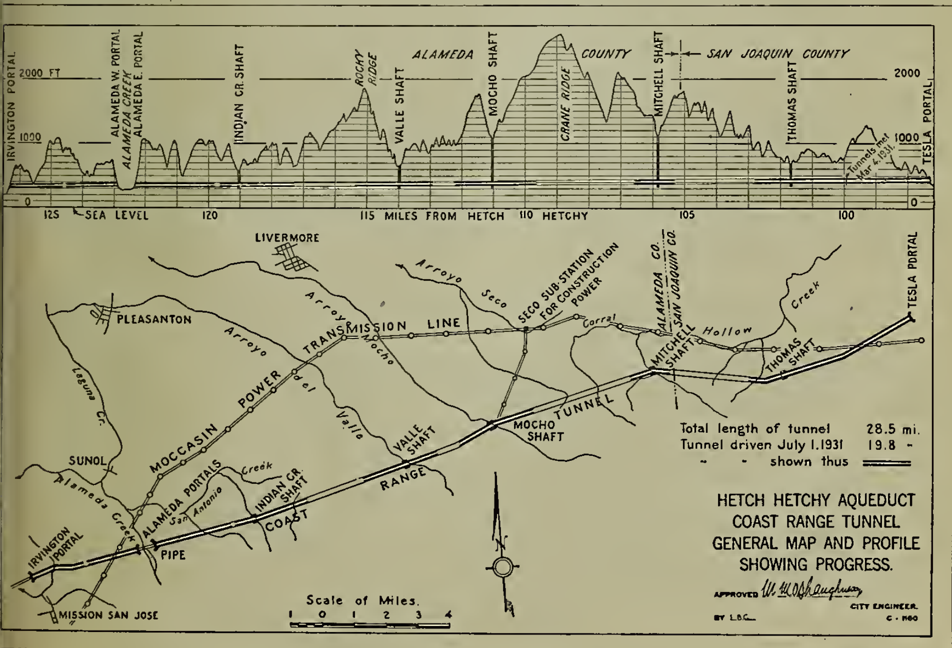
The Hetch Hetchy Project is making substantial progress toward completion. 'he final tunnel, through the Coast Range, 28.5 miles in length, is being driven ·om 12 headings with a progress of about 3,000 feet per month. To date, July 1, 931, 19.8 miles of this tunnel have been driven and over 3¼ miles lined with con-·ete by the gunite process, and it is predicted that with present progress it will be ɔmpleted and ready to carry water by the end of 1933.

One other unit of the aqueduct remains to be completed, the San Joaquin Valley ipe line, 47.4 miles in length. Up to the present time this construction has been eld in abeyance, to allow the tunnel work to progress further, so that tunnel and ipe might be finished simultaneously. However, a long succession of years of eficient rainfall in the Bay region have so seriously impaired the supply drawn from ıe City's local sources that it has been considered advisable to proceed immediately 'ith construction of this remaining pipe line so that it would be possible to secure ı emergency supply by building a temporary pipe line from Tesla Portal and pump-ıg Hetch Hetchy water over the summit of the Coast Range. Upon completion f the tunnel, the emergency pipe line could be salvaged for use in other parts of ıe water system.



This project is under construction by the City and County of San Francisco t furnish ultimately 400 million gallons of water daily for domestic use. As the water impounded at high elevation, it is feasible and practical to install several power plan that will produce 250,000 horsepower of hydro-electric energy for general lightin heating, and other civic power purposes.

The rugged, granite watersheds of over 420,000 acres of uninhabited lan above our intakes, are topped easterly by the Sierra Nevada with peaks over 13,0(feet in elevation. Waters from the melting snows and glaciers are now impounde in two reservoirs, Hetch Hetchy and Lake Eleanor, in which storage has alrea been developed to produce sufficient water for a population of 2,000,000 people.

The history of the steps which led to the City's gigantic undertaking is high interesting, but the space available will allow only a brief outline of the mo important happenings. Until 1858, San Francisco secured its water from wells ar springs and from peddlers' water carts. In that year a number of San Francis business men organized a water company which flumed in a supply of two milli gallons daily from Lobos Creek, emptying into the Golden Gate, pumped it reservoirs and distributed it through pipes to the consumers. As time went on th company gradually extended its pipes into San Mateo County and eventually acro San Francisco Bay into Alameda County. With an eye to the almighty dollar, tl company was always reluctant to develop additional supply. A strong sentime developed fifty-seven years ago, for a municipally owned supply, but its advocat never made substantial progress until the adoption of the City's new charter in 190

In 1901 the City Engineer made studies of a number of streams and lakes th could possibly be utilized by San Francisco and from these he selected the Tuolum River as the most available. Filings on this river flow, made under the Californ law, secured the water for the City, but the location of the two reservoir sites, Het Hetchy and Lake Eleanor, within Yosemite National Park, introduced a complicati of dealing with a Washington official, the Secretary of the Interior. The City application for permission to build dams at these points was twice rejected by th official in 1903. The application was again presented in 1908 and Secretary Garfie granted a limited permit to develop Lake Eleanor. The citizens thereupon vot two bond issues, one of $600,000 in 1908, and one of $45,000,000 in 1910 to co struct its water system. The action of the succeeding Secretary in proposing to wit draw the greater part of the Hetch Hetchy area included in the permit, caused t City to apply to Congress for a definite grant of the required privileges.

The City, in 1911, engaged John R. Freeman of Providence, R. I., to prepar brief and help present its case. Mr. Freeman redesigned the entire project in light of modern engineering practice, to what is commonly called the "Freeman Pla under which the system is now being built. This plan provides for an ultim delivery of 400 million gallons daily, against the 60 million gallons daily origina contemplated, and will bring the water to San Francisco by gravity, obviating t endless, needless, and expensive pumping of water over the Coast Range. The n plan provides, in addition, power development exceeding 250,000 horsepower wh was not originally contemplated.

An Advisory Board of Army Engineers, appointed by the President, studied eighteen alternative sources of water supply, and in February, 1913, approved the City's selection of the Tuolumne River as the best. After extended arguments before Congress, the Hetch Hetchy grant, known as the "Raker Act", was passed by both Houses and was signed by President Wilson on December 19, 1913. The act was later accepted by the City and the first construction contract was let in July, 1914.

The Raker Act contains a number of requirements, e.g., the construction of a dam of certain height, the development of certain amounts of hydro-electric power, and other conditions that necessitated immediate construction of the Mountain Division of the project and the Moccasin power system. Another condition is that the City use "the waters it now has" before using the Tuolumne water. It has generally been estimated that the local water system formerly owned by Spring Valley Water Company, but taken over by the City on March 3, 1930, had sufficient capacity to supply the City's needs until 1932 or later, so it was planned to complete the Hetch Hetchy system by the most economical program by that date. Postponement of the predicted date of completion from 1932 to 1933 has been caused by delays due to the installation of various safety devices as a result of a gas explosion in the Mitchell Tunnel in July, 1930.

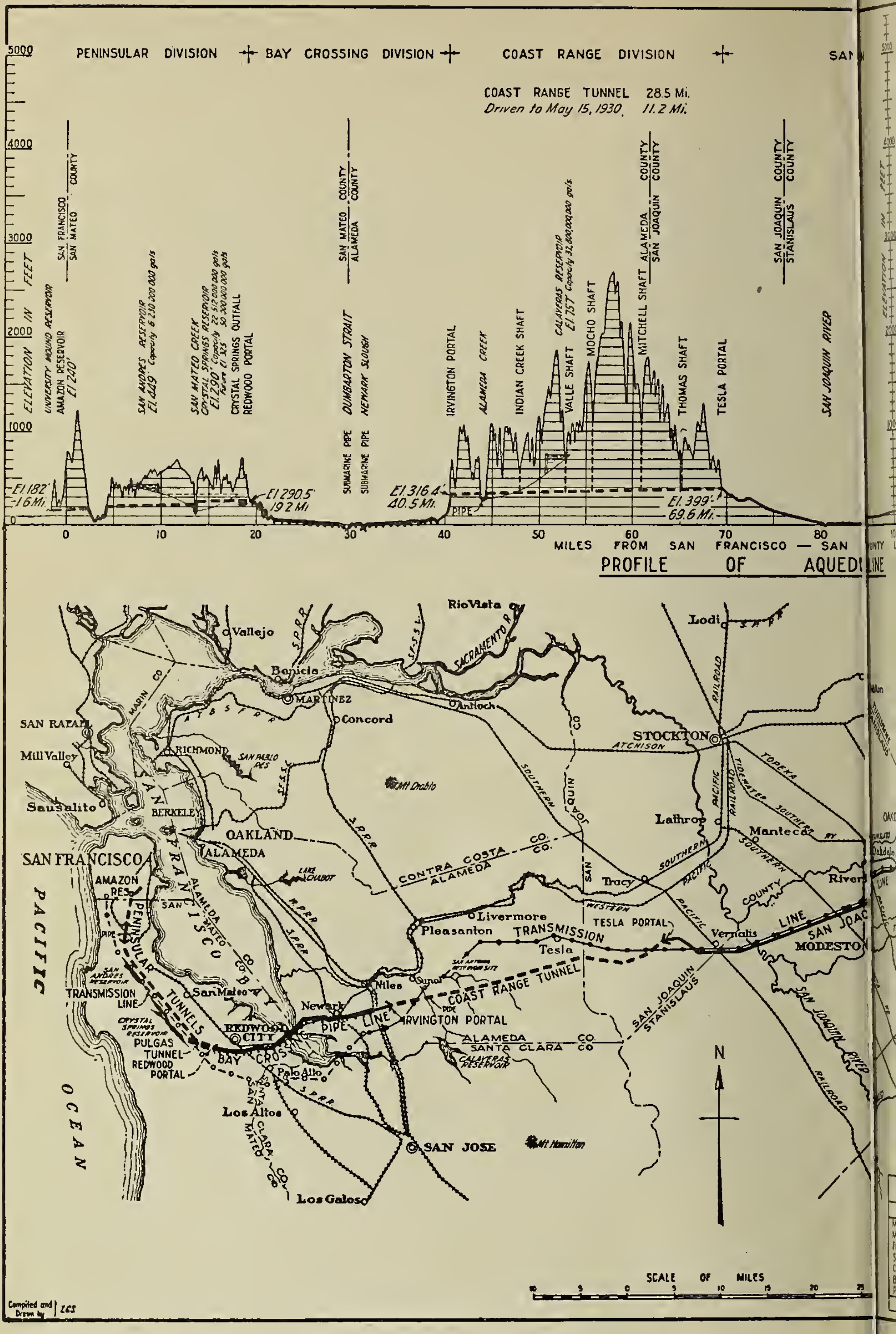
The principal features of the project are as follows:

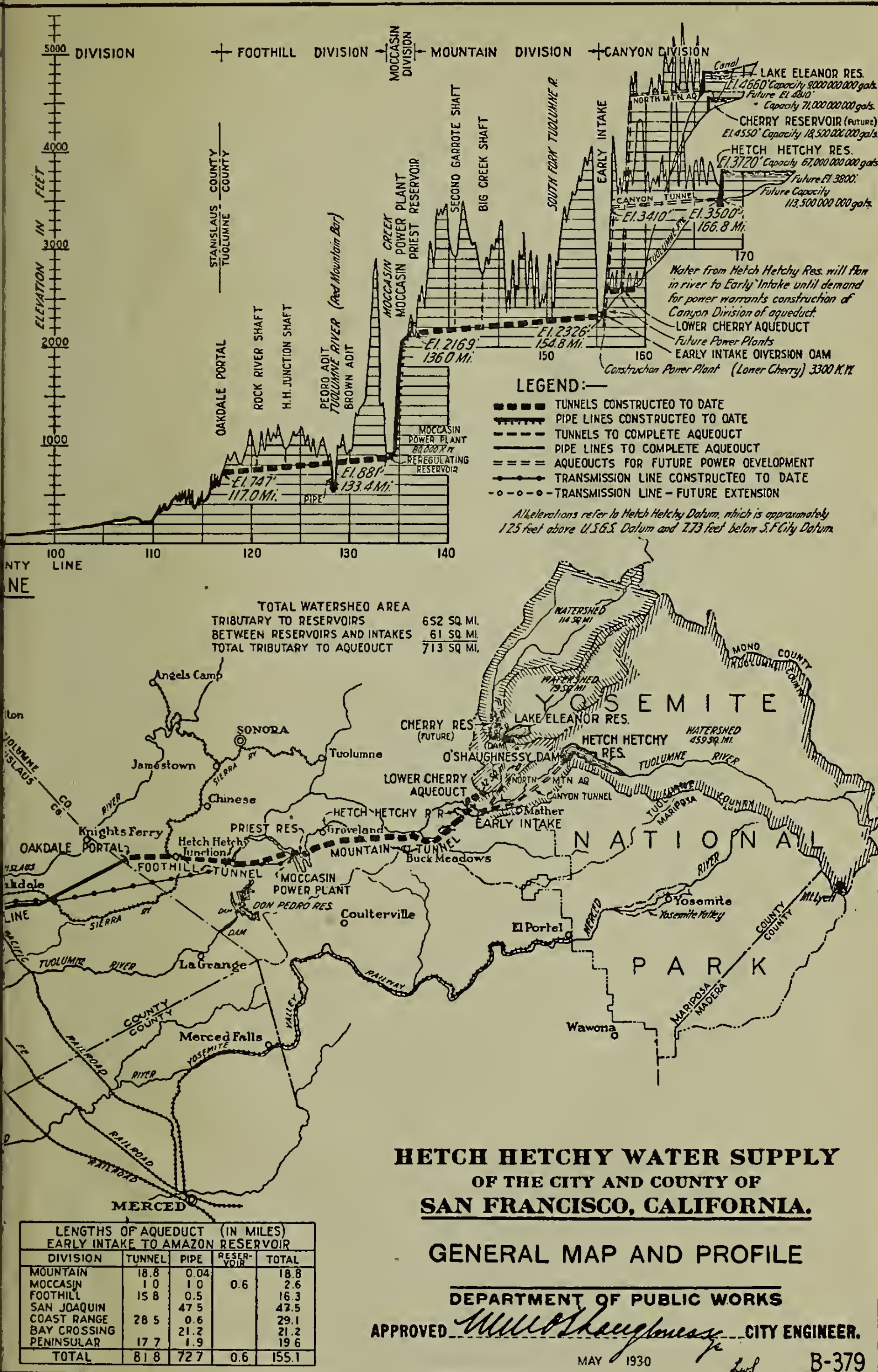
O'Shaughnessy Dam is a cyclopean concrete arched gravity dam across the Tuolumne River at the narrow outlet of what was Hetch Hetchy Valley. The dam has a total height of 344½ feet, of which 118 feet is below stream bed. Crest elevation is 3726.5 feet. The foundation has been built 298 feet thick to support a future dam 85½ feet higher than the present, or 430 feet high. The dam contains 398,516 cubic yards of concrete. It is an outstanding model of good construction and contains all the modern features to provide safety, such as contraction joints with copper water stops, inspection galleries and wells, complete drainage system, and a complete system of triple control outlet conduits. Siphon spillways are used. The dam was completed in 1923 at a cost of approximately $7,000,000.

Hetch Hetchy reservoir is 7½ miles long and stores 67 billion gallons, as much water as San Francisco now uses in 3½ years. The future dam will almost double this capacity. The water comes from a watershed of 459 square miles of the northern part of Yosemite National Park, from granite mountains rising to 13,000 feet elevation, in which there is no permanent habitation, and therefore it is absolutely pure. Chemical analysis shows 15 p. p. m. total solids, with hardness 2.6.

Lake Eleanor, holding nine billion gallons, is formed by a buttressed arch concrete dam 1260 feet long, 70 feet high, with crest at 4661 feet elevation. Plans for the future contemplate a rock fill dam 235 feet high which will make a lake eight times the size of the present one, or about the size of the present Hetch Hetchy.

The water from Lake Eleanor flows down creek bed, concrete canal and tunnel to meet the Hetch Hetchy water at Early Intake, 12 miles down the Tuolumne River from O'Shaughnessy Dam. Some of the Lake Eleanor water is used to operate a 4500 horsepower electric plant which not only produced adequate power to carry


PENINSULAR DIVISION
BAY CROSSING DIVISION
COAST RANGE DIVISION
COAST RANGE TUNNEL 28.5 Mi.
Driven to May 15, 1930 11.2 Mi.
ELEVATION IN FEET
UNIVERSITY MOUND RESERVOIR
AMAZON RESERVOIR
El. 240'
SAN FRANCISCO COUNTY
SAN MATEO COUNTY
SAN ANDRES RESERVOIR
El. 449'
SAN MATEO CREEK
CRYSTAL SPRINGS RESERVOIR
El. 290'
CRYSTAL SPRINGS OUTFALL
REDWOOD PORTAL
SAN MATEO COUNTY
ALAMEDA COUNTY
DUMBARTON STRAIT
NEWARK SLOUGH
SUBMARINE PIPE
IRVINGTON PORTAL
ALAMEDA CREEK
INDIAN CREEK SHAFT
CALAVERAS RESERVOIR
El. 757'
VALLE SHAFT
MOCHO SHAFT
MITCHELL SHAFT
ALAMEDA COUNTY
SAN JOAQUIN COUNTY
THOMAS SHAFT
TESLA PORTAL
SAN JOAQUIN COUNTY
STANISLAUS COUNTY
SAN JOAQUIN RIVER
El. 182'
1.6 Mi.
El. 290.5'
19.2 Mi.
El. 316.4'
40.5 Mi.
PIPE
El. 399'
69.6 Mi.
MILES FROM SAN FRANCISCO — SAN
PROFILE OF AQUEDU
Rio Vista
Lodi
Vallejo
Benicia
MARTINEZ
Concord
Antioch
SACRAMENTO R.
SAN RAFAEL
Mill Valley
Sausalito
RICHMOND
SAN PABLO RES.
BERKELEY
OAKLAND
ALAMEDA
SAN FRANCISCO
AMAZON RES.
PACIFIC OCEAN
SAN FRANCISCO BAY
Mt. Diablo
LAKE CHABOT
CONTRA COSTA CO.
ALAMEDA CO.
STOCKTON
ATCHISON
TOPEKA
Lathrop
Manteca
SOUTHERN PACIFIC
TIDEWATER SOUTHERN
Tracy
Livermore
Pleasanton
TRANSMISSION LINE
Tesla
TESLA PORTAL
Vernalis
MODESTO
SAN JOAQUIN STANISLAUS
COUNTY LINE
COAST RANGE TUNNEL
Niles
Sunol
Newark
PIPE LINE
IRVINGTON PORTAL
ALAMEDA CO.
SANTA CLARA CO.
CALAVERAS RESERVOIR
PENINSULAR
TRANSMISSION LINE
SAN ANDRES RESERVOIR
San Mateo
CRYSTAL SPRINGS RESERVOIR
TUNNELS
PULGAS TUNNEL
REDWOOD PORTAL
REDWOOD CITY
BAY CROSSING
Palo Alto
Los Altos
SAN MATEO CO.
SANTA CLARA CO.
SAN JOSE
Mt. Hamilton
Los Gatos
SAN JOAQUIN RIVER
RAILROAD
N
SCALE OF MILES
Compiled and Drawn by ZCS



LENGTHS OF AQUEDUCT (IN MILES) EARLY INTAKE TO AMAZON RESERVOIR				
DIVISION	TUNNEL	PIPE	RESERVOIR	TOTAL
MOUNTAIN	18.8	0.04		18.8
MOCCASIN	1.0	1.0	0.6	2.6
FOOTHILL	15.8	0.5		16.3
SAN JOAQUIN		47.5		47.5
COAST RANGE	28.5	0.6		29.1
BAY CROSSING		21.2		21.2
PENINSULAR	17.7	1.9		19.6
TOTAL	81.8	72.7	0.6	155.1

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.

GENERAL MAP AND PROFILE

DEPARTMENT OF PUBLIC WORKS

APPROVED M.M. O'Shaughnessy CITY ENGINEER.

MAY 1930

B-379

on the mountain construction activities but also brought the City over $500,000 revenue from sale of surplus power. The future program calls for two hydro-electric plants near Early Intake, which will produce 100,000 horsepower. One will use water from Hetch Hetchy, the other from Lake Eleanor and Cherry Creek.

At Early Intake, 155 miles from San Francisco, a concrete diversion dam of pure arch type, 81 feet high with crest elevation 2356 feet, turns the water into the aqueduct leading to the City. The first unit of aqueduct is a tunnel, 19 miles long, of which the first seven miles, in granite, are excavated 13 feet, 4 inches by 14 feet, 3 inches and are not lined with concrete. The next 12 miles are lined with concrete to a horseshoe shape 10 feet, 3 inches in diameter. The 19 mile tunnel cost approximately $11,000,000.

At the end of this tunnel, the water enters Priest Reservoir, which with storage capacity of two days' flow of the aqueduct, serves as a forebay or regulating reservoir for the operation of Moccasin Power House. Priest Dam is an earth and rock fill structure 1160 feet long, 145 feet high, with flexible, concrete core wall. The upstream and downstream toes consist of rock spoil from the tunnels. The remainder of the dam consists of earth and rock, part of which in the upstream side was placed by the hydraulic method and part by dump cars from steam shovel. The dam contains 717,283 cubic yards of earth and rock and 17,043 cubic yards of reinforced concrete core wall. It cost approximately $1,000,000.

The water leaves Priest Reservoir through the Power Tunnel, 13 feet diameter and one mile long, which ends in a surge shaft 40 feet diameter and 160 feet high. From this, three pipe lines 104 inches diameter lead to the power house. One is capped for future extension. The others, branching twice and reducing in diameter, terminate as eight nozzles 11 inches in diameter which discharge against the water wheels in the power house at a pressure of over 500 pounds per square inch.

Moccasin Power House is a California Mission type building with steel frame and reinforced concrete walls and tiled roof. It is 225 feet long, 98 feet wide and 67 feet high. The machinery consists of four 20,000 kv-a. generators, each mounted on a shaft with two 12,500 horsepower Pelton impulse water wheels. The static head is 1316 feet, with needle nozzles at 924 feet elevation. The power house is capable of producing 500,000,000 kilowatt-hours annually, which is equivalent to 33 per cent of the total power consumption in San Francisco. Power is transmitted at 120,000 volts, over the City's tower line in two circuits, 98½ miles to San Francisco Bay, at Newark. The power house, penstock lines, and transmission lines cost $7,000,000.

The water from the power house tail race is caught in Moccasin Re-regulating Reservoir to equalize the flow before it enters the next section of tunnel aqueduct. The dam which forms this reservoir is an earth and rock fill, 850 feet long and 50 feet high, containing 143,000 cubic yards of embankment, with a monolithic reinforced concrete core wall containing 3600 cubic yards.

Leading from this reservoir through the foothills of the Sierra Nevada is a 16 mile tunnel consisting of about equal lengths of lined and unlined sections of the same characteristics as those of the Mountain Division tunnel previously mentioned.

This tunnel was driven partly by contract and partly by day labor. The City's direct day labor employes drove tunnel at $35.53 per foot against the contractors' cost of $40.49, and placed concrete lining at $36.11 as against the contractors' $47.38 per foot. The Foothill Tunnels cost approximately $8,000,000.

At Mile 5 the tunnel is interrupted by a pipe siphon ½ mile long, passing under the Tuolumne River at Red Mountain Bar. This pipe is 9½ feet in diameter and is lined with concrete. The submerged portion is enveloped in a two foot layer of concrete. Contract will soon be let for completion of this pipe. Plans have been prepared for a power plant here, which could be built for $1,000,000 and produce an income of $500,000 annually, by using the surplus water which would not be required in San Francisco.

Leaving the foothills, the water will enter the pipe line across the San Joaquin Valley from near Oakdale to Tesla Portal. Eventually three pipes over six feet in diameter will be necessary to equal the capacity of the tunnels, which with a fall of 3½ feet per mile is 460 million gallons daily, but the initial pipe will be five feet diameter with capacity of 60 million gallons daily. This pipe, as noted in the introductory paragraphs, is now under construction. It is located on a strip of the City's land 110 feet wide, extending across the valley, one portion of which is at present occupied by the City's power transmission line. The cost of this work approximates $5,000,000.

From the San Joaquin Valley westerly, 1400 men are at present driving the Coast Range Tunnel. This work consists of a 25 mile continuous tunnel, the longest ever attempted by man, and a 3.6 mile tunnel, separated by a pipe line 0.6 mile in length across the valley of Alameda Creek. The finished tunnel is a 10 feet, 6 inch diameter circle, with concrete lining varying in thickness from six inches to two feet. The driving of this tunnel is particularly difficult and the overcoming of difficulties encountered in its construction is reflecting great credit on the men engaged in the work.

The tunnel is located practically along the pioneer line selected by Mr. Freeman in 1912 but as a result of extensive geological studies supplemented by diamond drill borings, the City Engineer shifted the line southerly to avoid, so far as possible, the Cretaceous formation which caused so much trouble in the old Tesla coal mines nearby. In the 25 mile tunnel, five shafts were sunk, from each of which tunnel was driven east and west. On March 4, 1931, the first tunnel was holed through from Tesla Portal to Thomas Shaft, a section 4.4 miles in length. Placing of concrete lining in this section has just begun and should be completed by March, 1932. By August, 1931, the two sections of tunnel from Indian Creek to Irvington should be "holed through."

In places the ground penetrated is very unstable and has a pronounced tendency to swell. This condition has been met by lining the tunnel with gunite concrete as soon as possible after opening up the ground. To date about 3½ miles of tunnel have been so lined. Water-bearing seams in the rock are made tight by forcing cement grout into them by compressed air. The setting of this grout shuts off the water in the seams from the tunnel. Occasional occurrence of methane presents

serious difficulty. This is the gas that constitutes some 80 per cent of the natural gas that is used for general heating purposes. A mixture of methane and air in certain proportions is highly explosive and elaborate precautions must be taken to prevent accidents.

From this tunnel, the aqueduct continues as a pipe line 21 miles long, crossing San Francisco Bay and terminating in Pulgas tunnel, 1¾ miles long, which discharges into Crystal Springs Reservoir. The pipe is five feet diameter riveted steel, except at a navigable slough and the navigable portion of the Bay at Dumbarton Strait, where 42 inch diameter, submerged, flexible joint, cast iron pipe is used. The deep portion of the Bay is crossed by 0.6 mile of the submerged pipe laid in a trench excavated in the bottom at a maximum depth of 70 feet below water. The end of the submerged pipe enters a concrete caisson 80 feet in diameter, resting on over 700 piles, which is the first pier of a bridge of 36 steel spans each 105 feet long, extending to the shore. The construction of the concrete caisson was exceedingly difficult. In it connections are provided for three additional submerged pipes and it may even be used for the terminus of a future tunnel under the Strait. The bridge is designed for two pipes six feet, four inches diameter. The Bay Crossing Division cost about $6,000,000.

The water will flow by gravity—without pumping—from Moccasin Power House at elevation 920 feet to the terminal tunnel at Crystal Springs Reservoir at 290 feet or may later be continued to San Francisco direct, at 250 feet. The purchase of the existing system of the Spring Valley Water Company for $40,000,000, taken over by the City on March 3, 1930, provided an excellent receiving reservoir (Crystal Springs) of 23 billion gallons capacity, close to San Francisco.

The Hetch Hetchy system with gravity aqueduct, when completed in 1933, will have cost about $82,000,000, which by capitalizing the $2,000,000 annual power income of the last six years may reasonably be divided into $52,000,000 for water and $30,000,000 for power. Any expense for temporary pipe line over the Coast Range will be in addition to this.

The design and construction have been characterized by care and conservatism. The work is being prosecuted efficiently and economically, largely by day labor under the control of the City Engineer and his staff of able assistant engineers.

FINANCE—A $600,000 bond issue voted in 1908 provided for purchase of watershed lands and water rights.

A $45,000,000 bond issue voted in 1910 has financed the completed work, including the Moccasin Power development with an annual revenue of approximately $2,000,000 and the Bay Crossing Division bringing in $250,000.

A $10,000,000 bond issue voted in 1924 provided funds for the Foothill Division and shaft sinking in the Coast Range.

On May 1, 1928, a bond issue of $24,000,000 was voted to complete the San Joaquin Pipe Line and the Coast Range tunnels and $41,000,000 to purchase the Spring Valley Water Company's system.

Of the last $24,000,000 Hetch Hetchy bond money $12,000,000 remained to be expended July 1, 1931.